

Some E2E work in support of AdvLIGO

Alan Weinstein, Caltech / LIGO
E2E meeting, May 23, 2001

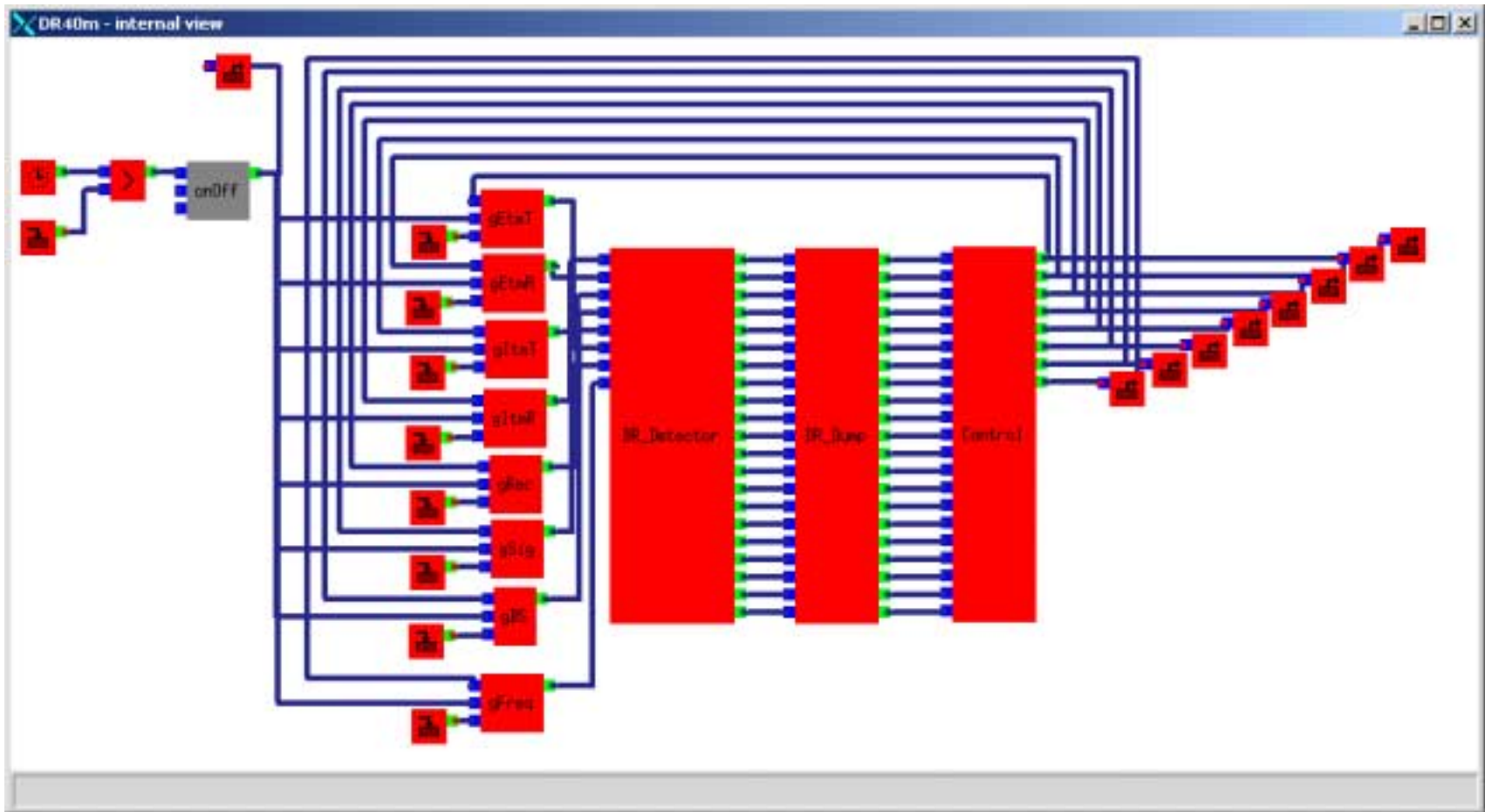
Scope

- I (AJW) have been pursuing E2E modeling of AdvLIGO with visiting grad student Guillaume Michel, and plan to continue this with a summer SURF student.
- PLEASE NOTE that the goal is NOT to model the 40m prototype. The 40m prototype exists ONLY to verify the AdvLIGO control scheme; it is NOT an end in itself. The goal of this study is to develop a deeper understanding of AdvLIGO, especially (but not limited to) lock acquisition.
- Our goal is to understand AdvLIGO (especially lock acquisition), and only then apply it to 40m parameters, to understand the degree to which the 40m prototype can help us gain confidence in AdvLIGO design.
- Our approach to this problem is incremental, and it will evolve as E2E, and our understanding of AdvLIGO, evolves.

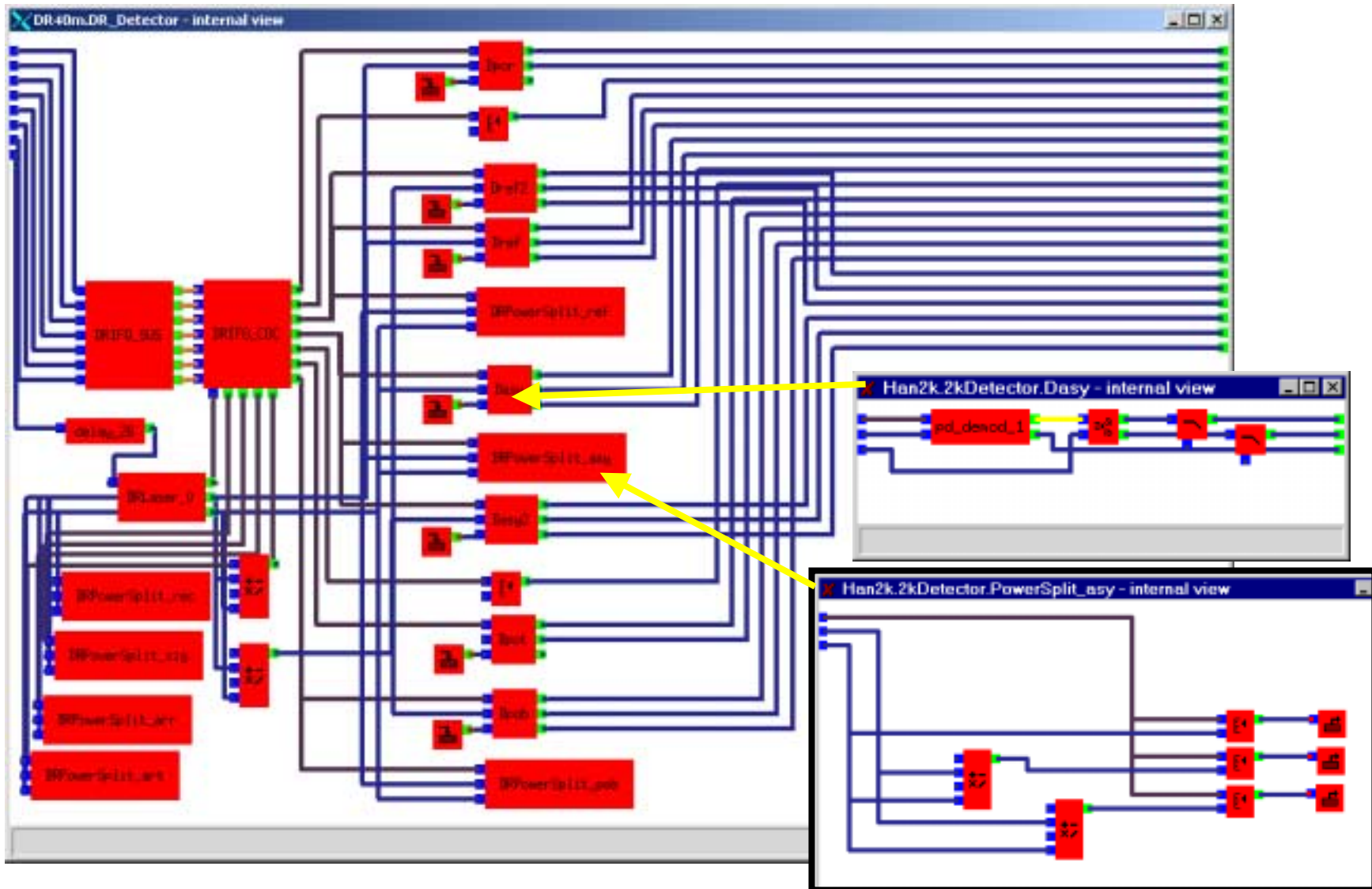
Proceeding in stages

- Step one: begin with the nicely tested, and very useful, Han2K model; and with Matt's algorithm for acquiring lock at LIGO I.
- Extend Han2K to include dual recycling -> DRLIGO
 - This work is done, except that primitives are used in place of a DR summation cavity. It was a lot of work!
 - Does not, of course, yet include multiple pendula or active seismic isolation.
 - All parameters in `e2eDB.mcr`. Easy to change from 4K to 40m.
 - We'd love to contribute to the effort to build a DR cavity; but see comments below
 - Validate the DRLIGO model by comparing DC fields everywhere with Twiddle and analytic calculations. This is DONE, using a snapshot of AdvLIGO parameters as of Aug 2000. This includes:
 - Detuned SRC
 - Offset-locked arms, for DC demodulation
 - 9MHz and 180 MHz sidebands. All fields verified!
 - Learn how to *stay* in lock, and learn how to *acquire* lock

DRLIGO.box



DR_Detector

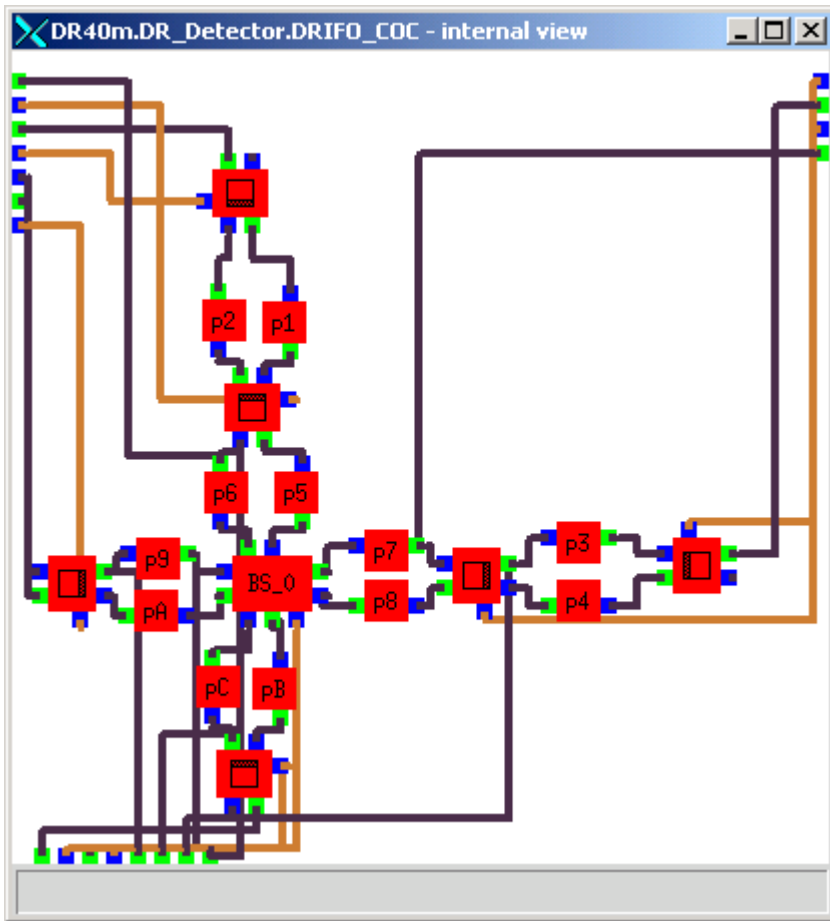


DRIFO_Sus

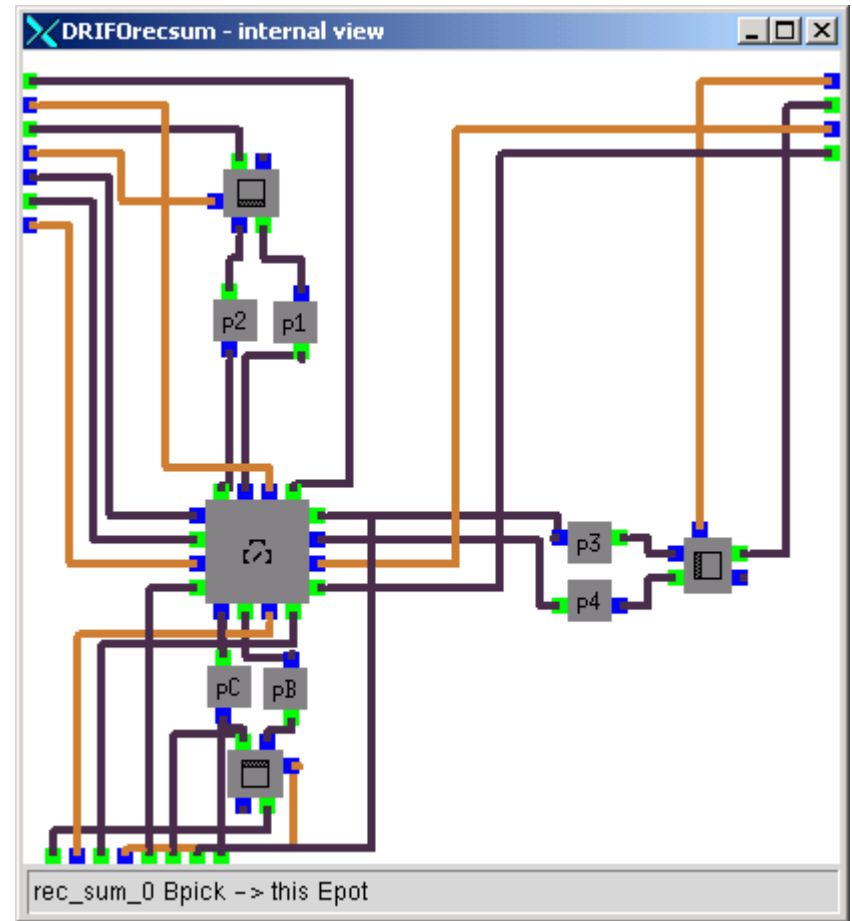


SeisLow added to the two ETMs, nowhere else.

DR_IFO



Using primitives

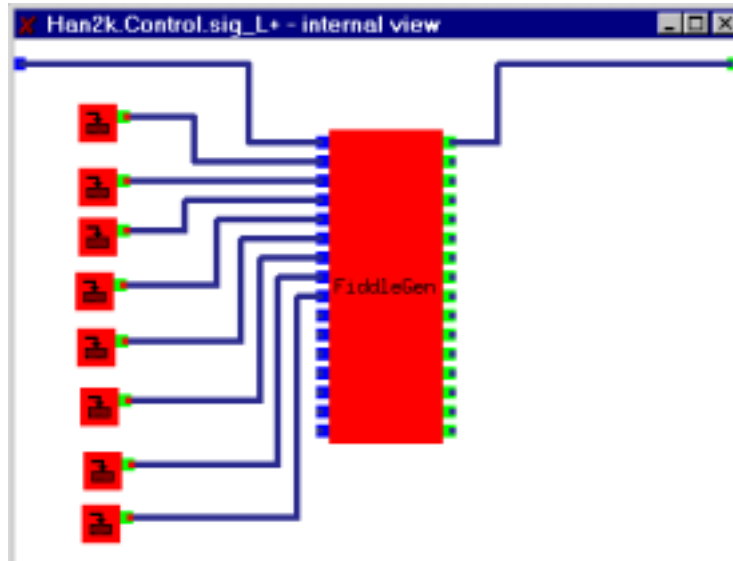
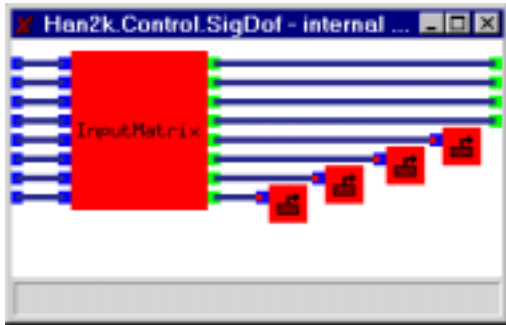
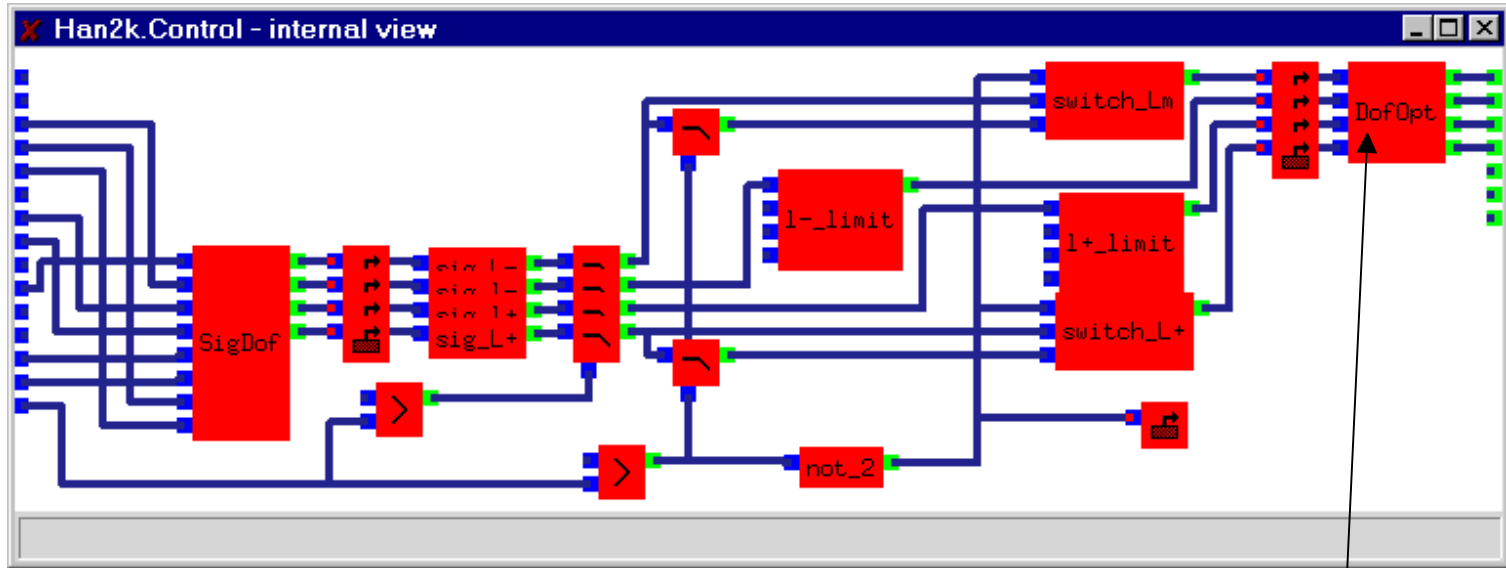


Using PR summcav.
Doesn't work (could be fixed)

Core optics

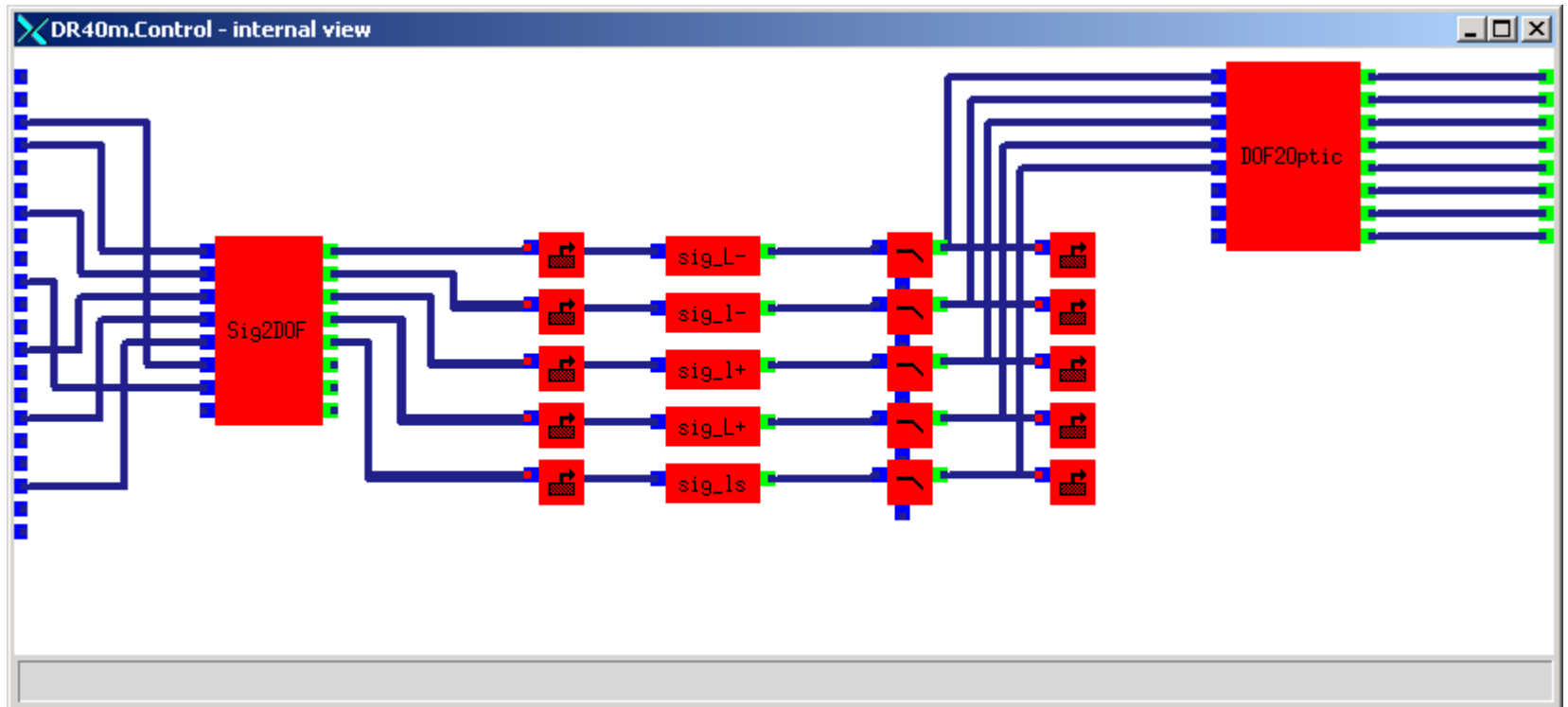
- Yes, a DR summation cavity is an essential ingredient in getting the AdvLIGO dynamics right, since the time it takes to run with primitives is prohibitively long.
- This is less important for the 40m; ratio of longest arm lengths to shortest (with `have_delay` on) is not anywhere near as large.
- Nonetheless, *much* can be learned about AdvLIGO with primitive-level optics, in reasonable amounts of time, with one change: make the 4K arms only 40m long.
- What is not simulated with high fidelity in this case? The time-constants for filling up the arm cavities with carrier light. What affect does that have?
- I claim (please correct me if I'm wrong) that it has little effect on the lock acquisition problem (although it obviously does affect the time it takes to acquire lock!). In particular, nothing in Matt's code, or in length-sensing-and-control (LSC), depends on the length of the arm cavities except for the L+ / L- feedback filters.
- So much can be learned about AdvLIGO “while we wait” for a DR summation cavity!

Han2K Control



#inputs Lp Lm elp elm
 #outputs zEtmT zEtmR zItmT zItmR
 $zEtmT = -(Lp + elp + Lm + elm);$
 $zEtmR = Lm + elm - Lp - elp;$
 $zItmT = elp + elm;$
 $zItmR = elp - elm;$

DRLIGO_control



- Just the bare-bones first attempt; not to acquire lock, just *stay* in lock!
- Guillaume is attempting to understand this using Han2K; still struggling after 2 months – it's a subtle problem!
- Will develop the freq-dependent filters, non-linear boosts, etc, then generalize Matt's lock acquisition algorithm.

Understanding Han2K control

- First step: construct a control matrix to keep the IFO in lock if it already there.
- Need to measure the DC coefficients: dS/dL (a 4x4 matrix, really 6x4, since there are 6 useful signal ports)
- Also measure at finite GW frequency: all 6x4 transfer functions
- Guillaume Michel has done this for Han2K (prior to doing it for DRLIGO).

Examples of TF Bode plots

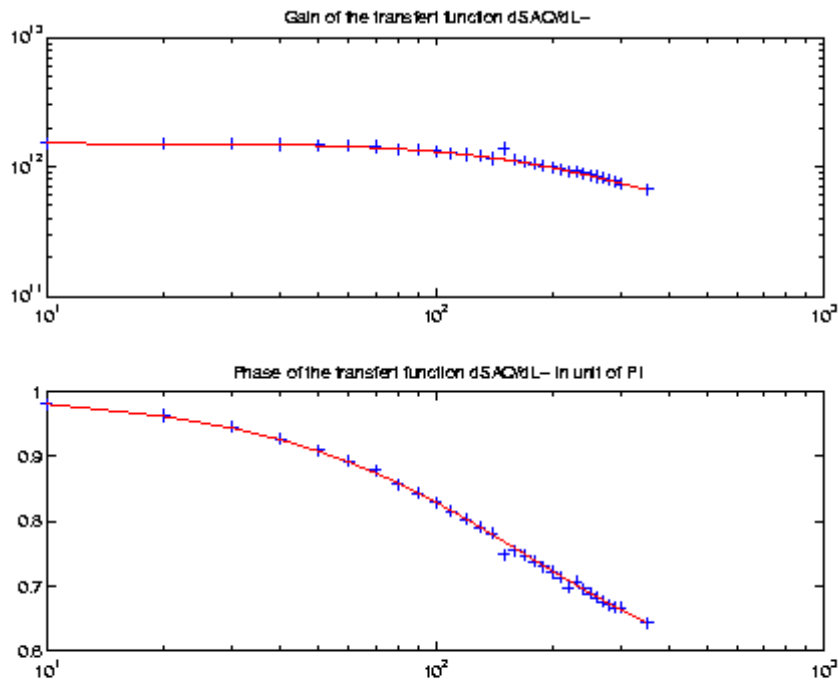


Figure 1: Transfer function open loop from L^- to S_{AQ}

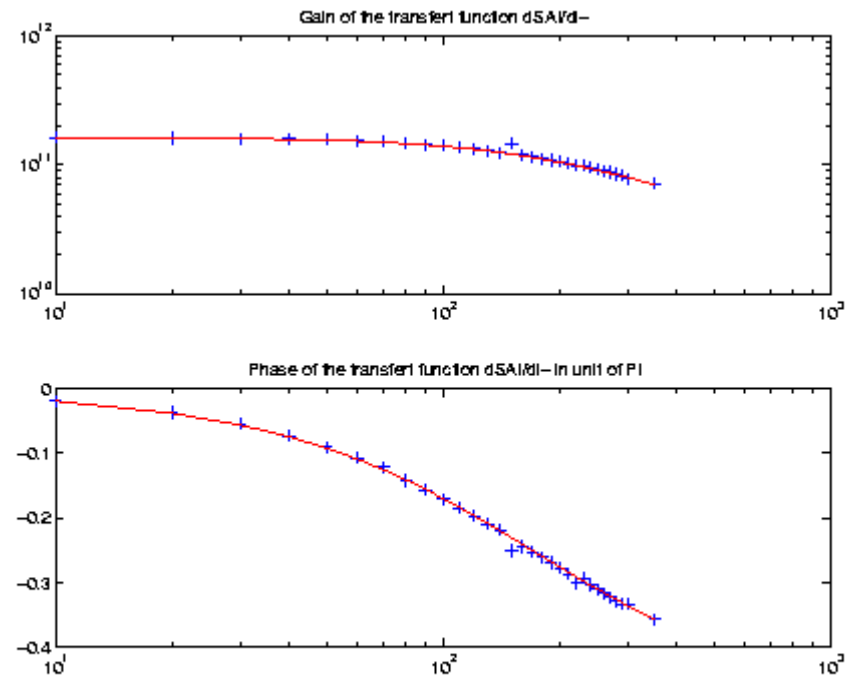


Figure 4: Transfer function open loop from I^- to S_{AI}

Fits to TF's using E2E

DOF \ SIG	S_{AQ} (in V)	S_{AI} (in V)	S_{PQ} (in V)	S_{PI} (in V)	S_{SQ} (in V)	S_{SI} (in V)
L^- (in m)	$\frac{-1.5225e^{12}}{1+i\frac{f}{170}Hz}$	$\frac{8.1741e^{10}}{1+i\frac{f}{170}Hz}$	$\frac{-2.225e^{11}}{1+i\frac{f}{170}Hz}$	$\frac{-4.2013e^{12}}{1+i\frac{f}{170}Hz}$	X	X
f^- (in m)	$\frac{-3.0286e^{12}}{1+i\frac{f}{170}Hz}$	$\frac{1.6861e^{11}}{1+i\frac{f}{170}Hz}$	X	$\frac{-8.3696e^{12}}{1+i\frac{f}{170}Hz}$	$\frac{6.8920e^9(1+i\frac{f}{27}Hz)}{1+i\frac{f}{2.13}Hz}$	X
L^+ (in m)	X	X	$\frac{-8.9090e^{12}}{1+i\frac{f}{2.13}Hz}$	$\frac{-1.6732e^{14}}{1+i\frac{f}{2.13}Hz}$	$\frac{4.0680e^{11}}{1+i\frac{f}{2.13}Hz}$	$\frac{-1.2541e^{12}}{1+i\frac{f}{2.13}Hz}$
f^+ (in m)	X	$\frac{5.1481e^9(1-i\frac{f}{370}Hz)}{1+i\frac{f}{2.13}Hz}$	$\frac{-1.7768e^{13}(1+i\frac{f}{400}Hz)}{1+i\frac{f}{2.13}Hz}$	$\frac{-3.3267e^{14}(1+i\frac{f}{770}Hz)}{1+i\frac{f}{2.13}Hz}$	$\frac{8.0687e^{11}(1+i\frac{f}{2300}Hz)}{1+i\frac{f}{2.13}Hz}$	$\frac{-2.4795e^{12}(1+i\frac{f}{950}Hz)}{1+i\frac{f}{2.13}Hz}$

Table 1: fitted transfert function open loop with E2E

Closed-loop TF's

(we don't understand them)

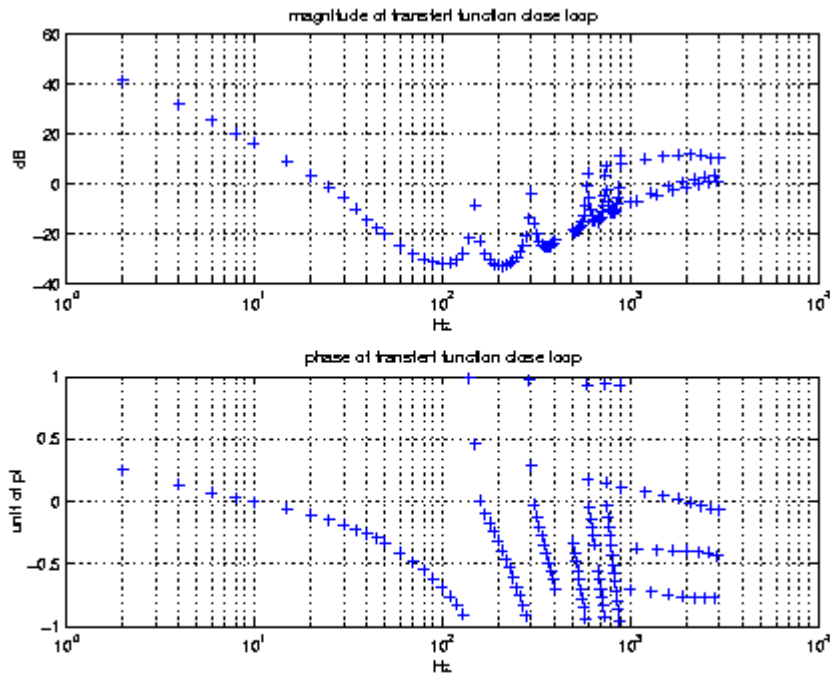


Figure 5: Transfer function close loop from L^- to S_{AQ}

Control

- I tend to approach these problems rather naively, so let me make some naïve statements and tell me how wrong I might be:
- Lock acquisition for a DR LIGO can be approached as a straightforward generalization of Matt's algorithm / code.
- Remember that there's no carrier in the SRC. Once you've got the carrier, 9 MHz, and 180 MHz resonating in the PRC, the resonance of the 180 MHz in the SRC is "easy" to establish.
- The biggest worry is that the IFO could enter into a longer list of "states" that are not the ones desired during the stansition through states 1-5 to lock acquisition. Exploring this is a proimary goal of the study.
- None of this depends on the length of the arms or the time-constants involved!
- More detailed modeling requires DR cavity, multiple pendula, thermal effects, etc. One step at a time!